



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> :	A1	(11) International Publication Number:	WO 98/14302
B23K 26/06		(43) International Publication Date:	9 April 1998 (09.04.98)

(21) International Application Number: PCT/DK97/00412

(22) International Filing Date: 30 September 1997 (30.09.97)

(30) Priority Data:  
 1067/96 30 September 1996 (30.09.96) DK  
 1091/97 23 September 1997 (23.09.97) DK

(71) Applicant (for all designated States except US): FORCHI INSTITUTET [DK/DK]; Park Alle 345, DK-2605 Brøndby (DK).

## (72) Inventor; and

(75) Inventor/Applicant (for US only): NIELSEN, Steen, Erik [DK/DK]; Nyvej 4, Meløse, DK-3320 Skævinge (DK).

(74) Agent: CHAS. HUDE A/S; H.C. Andersens Boulevard 33, DK-1553 Copenhagen V (DK).

(81) Designated States: AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GE, GH, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

## Published

With international search report.

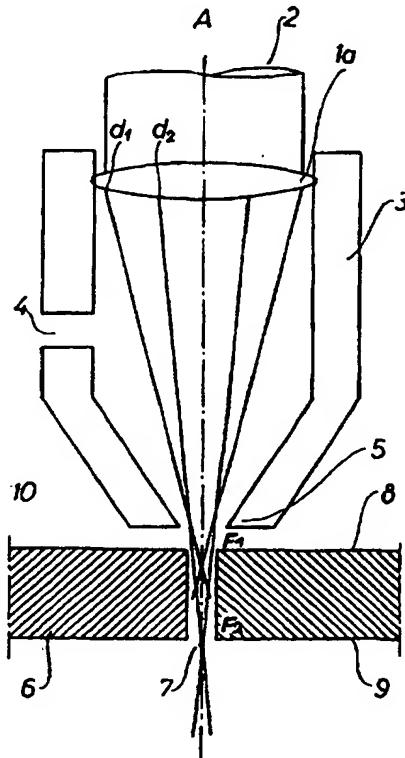
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

In English translation (filed in Danish).

(54) Title: A METHOD OF PROCESSING A MATERIAL BY MEANS OF A LASER BEAM

## (57) Abstract

A method of processing a material with a first and a second surface (8, 9) by means of a laser beam (2), which is focused by means of a multilens objective in a number of focal points ( $F_1, F_2 \dots F_n$ ), which are approximately positioned on a common axis with an angle to the first surface (8). The focal points are spaced apart and used for cutting plates, several focal points being utilized for melting/cutting the plate material. As a result a good cutting notch is obtained with a poor adhering of slags and a good separation of the cut parts.



**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TC	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakhstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

Title: A method of processing a material by means of a laser beam.Technical Field

The invention relates to a method of processing a material with a first and a second surface by means of a laser beam which for instance by means 5 of a multilens objective is focused in a number of focal points, where said focal points are approximately positioned on a common axis forming an angle with the first surface and are spaced apart.

Background Art

German Auslegeschrift No. 2,713,904 discloses a way of processing an 10 article by means of a laser beam, said laser beam being focused in two focal points by means of a multilens objective. This processing method is used for drilling holes, whereby one focused bundle of rays is used for a melting of the surface of the article and the second bundle of rays presents a focal point positioned below the focal point of the first bundle of 15 rays and is used for preheating the area surrounding the location of the article to be melted so as subsequently to be removed by way of evaporation. Such a processing method avoids to a certain degree formation of burrs at the edge of the hole. The lower focal point is, however, not utilized.

20 A growing demand has applied within the material processing industry employing lasers for a possibility of cutting in thick plates, such as steel plates of a thickness of 15 mm or more. As the cutting capacity of the laser beam is best on or adjacent the surface it is focused on, problems apply to transferring the effect to portions of the plate positioned below 25 said surface. Moreover, the second surface of the material is encumbered with problems of an increased amount of adhering slags and a poor cutting quality, which inter alia results in a poor separation of the cut parts and

may necessitate a finishing processing.

Brief Description of the Invention

The object of the invention is to provide a method of processing material by means of a laser, which ensures an improved processing quality in connection with thick materials. Furthermore, the expenditure of protecting gases must be low.

A method of the above type is according to the invention used for cutting plates, whereby several focal points are utilized for melting/cutting the plate material. The multilens objective has the effect that the total bundle of rays is relatively narrow, whereby the nozzle for protecting gases and consequently the expenditure of said protecting gases can be reduced correspondingly. It is well known that the protecting gases are very important for the quality and the cut.

According to a preferred embodiment of the invention, the focal points are positioned at a fixed distance relative to one another and to the first and the second surface.

It is advantageous for the complexity of the focusing optical instruments when the number of focal points is two.

It is furthermore advantageous when the distance between the head comprising the optical instruments and the first surface can be increased in such a manner that the focal point adjacent the second surface during the cutting can be caused to be positioned on the first surface, the so-called starting holes thereby being provided in an improved manner. In addition, the risk of the optical instrument being damaged by metal sprayings has been reduced.

A further advantage is found in connection with ignition, melting and removal of melt and slags by at least one of the focal points being positioned between the first and the second surface, adjacent the second surface or adjacent the first and the second surface, respectively.

- 5 In order to facilitate the penetration of the laser beam into the cutting notch it is furthermore advantageous when the focusing optical instruments focus the laser beam in several focal points, the distance of which from the second surface is increased concurrently with an increasing distance of the light from the central axis of the laser beam in such a
- 10 manner that the central portion of the laser beam is focused in the focal point adjacent the second surface.

#### Brief Description of the Drawing

Two embodiments of the invention are described in greater detail below with reference to the accompanying drawing, in which

- 15 Fig. 1a illustrates a laser cutting head with transmittent optical instruments,

Fig. 1b illustrates a laser cutting head with reflecting optical instruments,

Fig. 2a shows a transmittent optical instrument forming three focal points,

Fig. 2b shows a reflecting optical instrument forming three focal points,

- 20 Fig. 3a illustrates the cutting head of Fig. 1a at a distance from the surface, and

Fig. 3b illustrates the cutting head of Fig. 1b at a distance from the surface.

Best Mode for Carrying Out the Invention

Reference is first made to Fig. 1a, where a plate 6 to be cut by means of a laser is shown. The plate comprises a first surface 8 and a second surface 9. A movable, integrated optics/nozzle system, also called a cutting head 10, is provided above the first surface 8 of the plate 6. The cutting head 10 is movable in a plane parallel to the first surface 8 of the material to be cut in, whereby optional shapes can be cut in said material. The latter is known per se and is therefore not discussed in greater detail. Furthermore the cutting head 10 is movable to a predetermined degree perpendicular to the first surface 8 in such a manner that during the cutting it can enter an optimum distance relative to a flow of cutting gas and the focusing of the laser beam 2.

The cutting head 10 comprises a pressure chamber 3 with an inlet opening 4 allowing a continuous filling of cutting gases into said pressure chamber 15 3, as well as an outlet opening 5 directing the gas towards the cutting location. The gas used depends on the material to be cut, but typically it is oxygen in connection with ordinary steel to be burnt away, or an inert gas, such as nitrogen, in connection with stainless steel being melt away.

In addition, the cutting head 10 comprises an optical instrument 1a, 1b, 20 21a, 21b focusing a laser beam 2 in a number of focal points  $F_1$ ,  $F_2$ , ...,  $F_n$ . These focal points are scattered on a common axis A, which forms an angle, typically a right angle with the first surface 8 of the material to be cut. These focal points  $F_1$ ,  $F_2$ , ...,  $F_n$  are interspaced a fixed distance relative to one another and relative to the first and the second surface 8, 25 9 of the material. For illustrative reasons, the Figures 1a and 1b are diagrammatic vies of a cutting notch 7, in which the focal point  $F$  .... is positioned.

In the embodiment shown in Fig. 1, the optical instrument 1a, 1b is

formed such that the central portion of the instrument, i.e. within  $d_2$ , focuses the central portion of the laser beam 2 in the focal point  $F_2$  adjacent the second surface 9 of the material, whereas the circumferential portion outside  $d_2$  focuses the outer portion of said laser beam 2 in the 5 focal point  $F_1$  adjacent the first surface 8 of the material. In the illustrated embodiment, the focal point  $F_1$  is placed above the surface 8 in view of the cutting, but it is also possible to place all the focal points  $F_1, F_2, \dots, F_n$  between the first and the second surface 8, 9.

The optical instrument can be structured in many ways. The Figures illustrate simple embodiments using a lens 1a or a mirror 1b.  
10

The Figures 2a and 2b show embodiments of optical instruments 21a, 21b with several focal points  $F_1, F_2, \dots, F_n$ , only three being illustrated for the sake of clarity. In this case, the focal points of respective concentric portions of the optical instrument 21a, 21b are formed such that the focal 15 length decreases concurrently with an increasing distance from the centre.

The distance between the entire cutting head 10 and the first surface is variable in such a manner that during the starting procedure it can be increased whereby the focal point  $F_2$  ordinarily positioned adjacent the second surface 9 during the cutting can be caused to be positioned on the 20 first surface. The resulting increased distance between the cutting head 10 and the first surface 8 reduces the risk of sprayings of melt material returning through the nozzle 5 so as to destroy the optical instruments 1a, 1b, cf. Figures 3a and 3b where the diagrammatic cutting notch 7 has been maintained for illustrative reasons so as to provide an improved view 25 of the beam passage, but said notch does not, of course, exist before the cutting has been initiated.

Although the embodiments include simple lens members, it is also possible to use more complicated arrangements, such as combinations of lenses

which in combination form the desired number of focal points.

It is also possible to a certain degree to deviate from the exact axial positioning of the focal points or the right angle of this axis with the surface without deviating from the basic idea of the invention. Such a procedure  
5 is for instance possible as long as it is advantageous for the cutting speed that the cutting in the deep layers is performed involving a minimum displacement relative to the layers thereabove.

Claims

1. A method of processing a material with a first and a second surface (8, 9) by means of a laser beam (2), which for instance by means of a multilens objective is focused in a number of focal points ( $F_1, F_2, \dots, F_n$ ),  
5 which are positioned approximately on a common axis forming an angle with the first surface, and which are spaced apart relative to one another, used for cutting plates, several focal points being utilized for melting/cutting the plate material.
2. The use as claimed in claim 1, characterised in that the  
10 focal points ( $F_1, F_2, \dots, F_n$ ) are fixed spaced apart from one another and from the first and the second surface (8, 9).
3. The use as claimed in claim 1 or 2, characterised by the  
number of focal points ( $F_1, F_2, \dots, F_n$ ) being two.
4. The use as claimed in one of the preceding claims 1 to 3, characterised by at least one of the focal points ( $F_1, F_2, \dots, F_n$ ) being positioned between the first and the second surface (8, 9) adjacent the second surface (9) or adjacent the first and the second surface, respectively.  
15
5. The use as claimed in one of the preceding claims 1 to 4, characterised by the focal point ordinarily being positioned adjacent the second surface (9) during the starting of the cutting being caused to be positioned on the first surface (8).  
20
6. The use as claimed in one of the preceding claims 1 to 5, characterised by the central portion of the laser beam (2) being focused  
25 in the focal point ( $F_1$ ) adjacent the second surface (9).

7. The use as claimed in one of the preceding claims 1 to 6, characterised by the focusing optical instruments (1a, 1b, 21a, 21b) focusing the laser beam (2) in several focal points ( $F_1$ ,  $F_2$ , ...,  $F_n$ ), the distance of which from the second surface (9) being increased concurrently with the increasing distance of the light from the central axis of the laser beam.

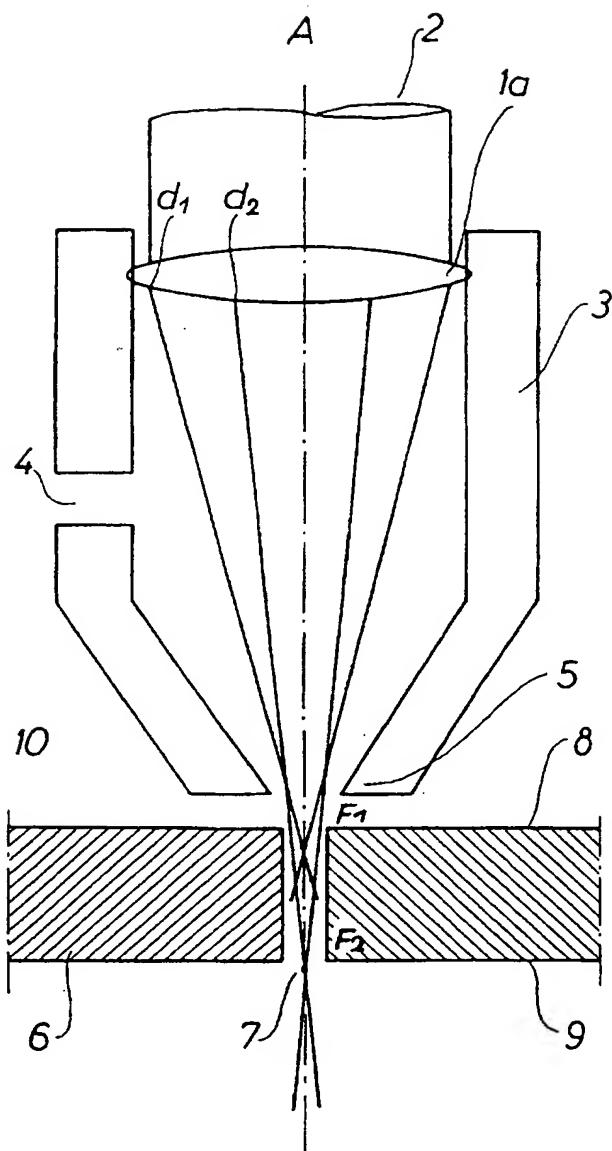


Fig. 1a

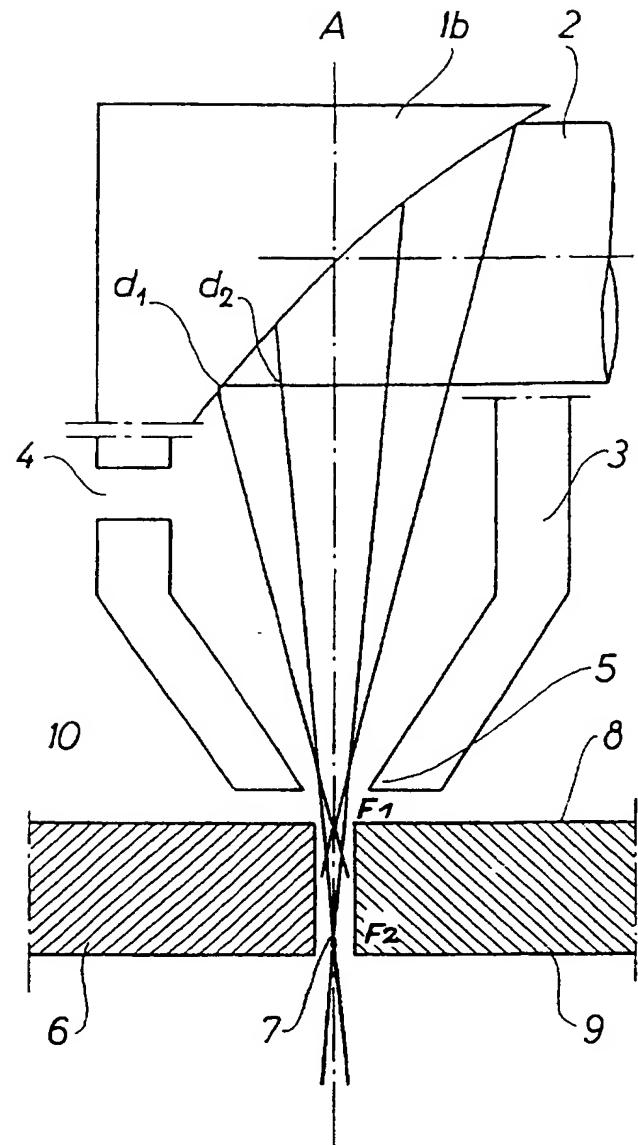
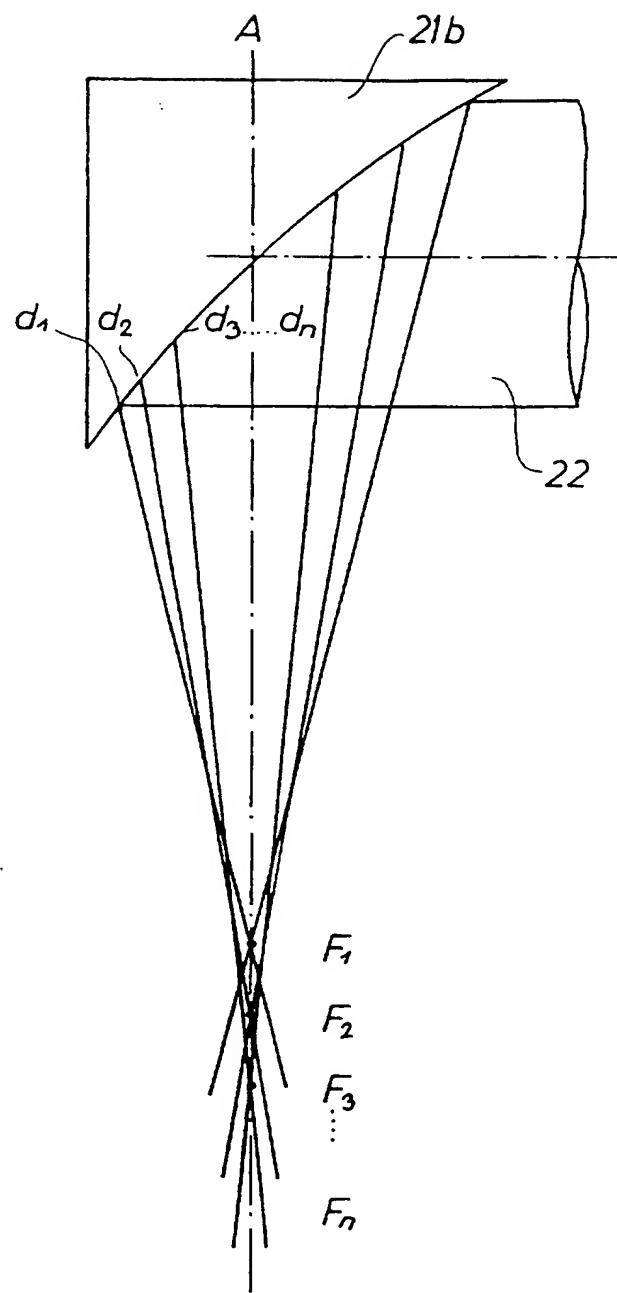
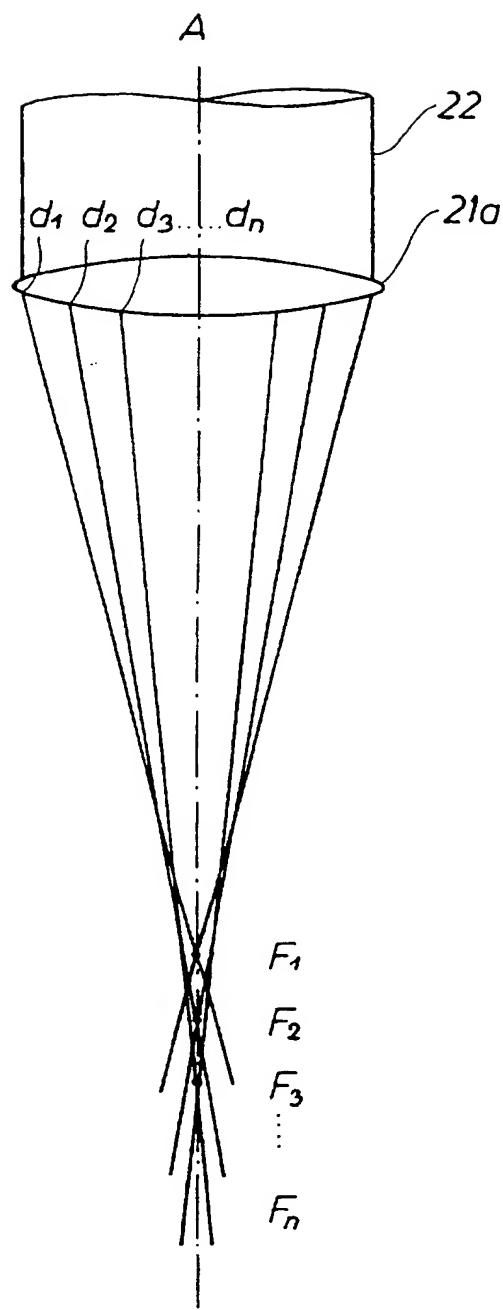


Fig. 1b

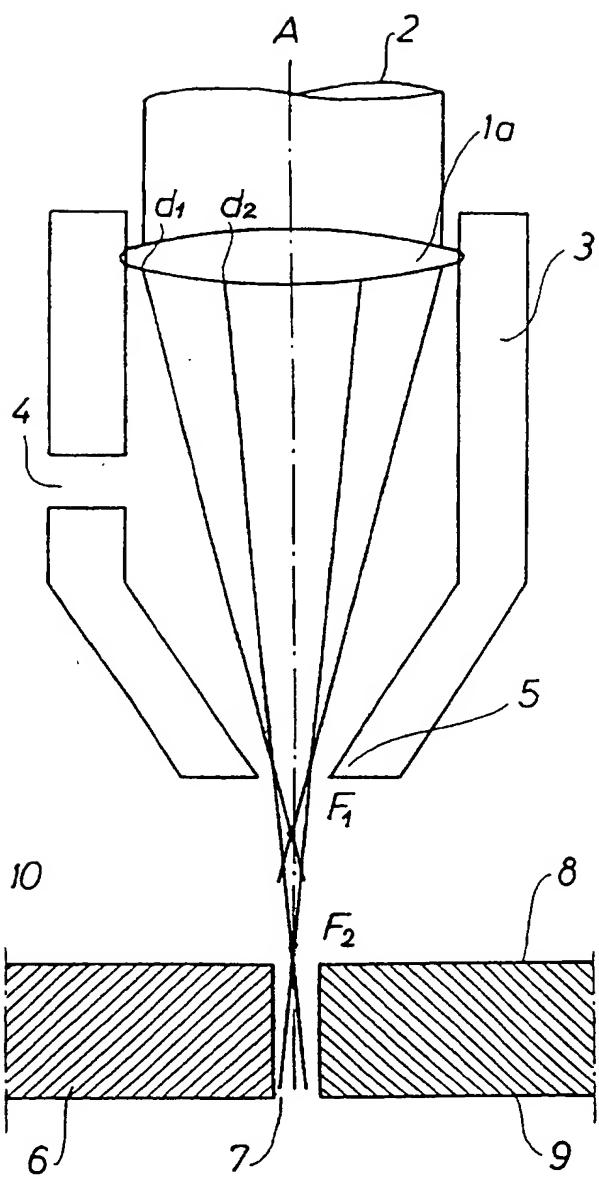
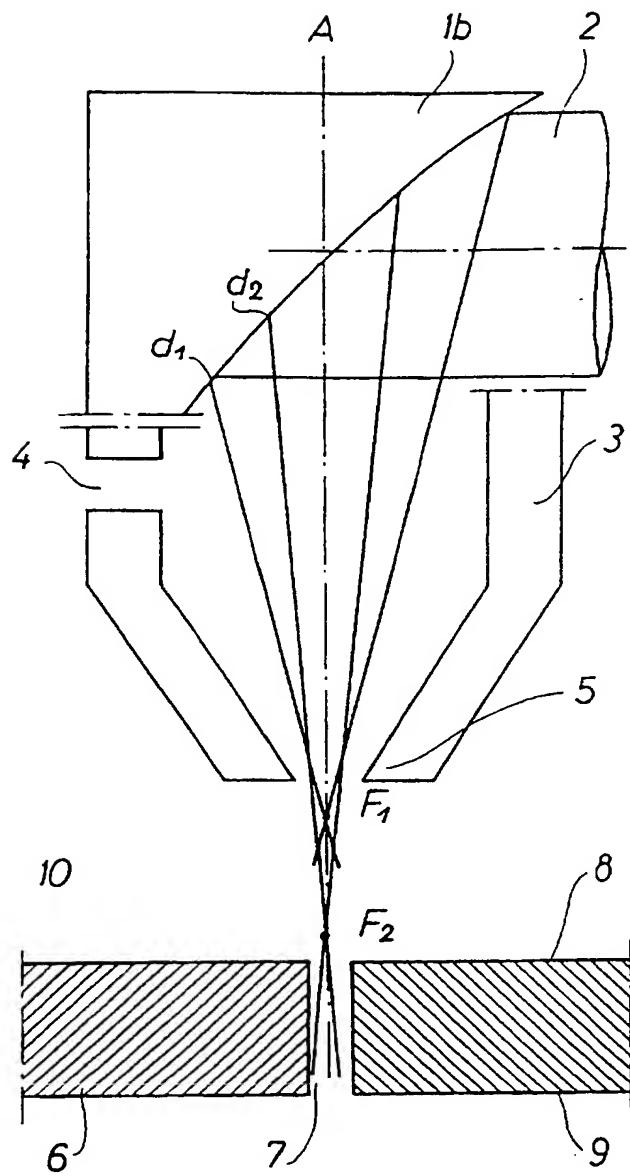


*Fig. 2a*

*Fig. 2b*

SUBSTITUTE SHEET (RULE 26)

3 / 3

*Fig. 3a**Fig. 3b*

SUBSTITUTE SHEET (RULE 26)

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/DK 97/00412

**A. CLASSIFICATION OF SUBJECT MATTER****IPC6: B23K 26/06**

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

**IPC6: B23K**

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

**SE,DK,FI,NO classes as above**

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**WPI****C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 4034745 A1 (FRIEDRICH-SCHILLER-UNIVERSITÄT), 18 July 1991 (18.07.91), column 5, line 34 - line 56, figures 2,3, abstract  --	1-7
X	DE 2713904 A1 (SIEMENS AG), 5 October 1978 (05.10.78), page 5, line 34 - page 8, line 2, figures 1-5  --	1-7
X	US 5521352 A (W.E. LAWSON), 28 May 1996 (28.05.96), column 2, line 3 - column 3, line 20, figure 1, abstract  --	1,2,3,4

 Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"I" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier document but published on or after the international filing date	"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"T" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search	Date of mailing of the international search report
6 March 1998	06-03-1998
Name and mailing address of the ISA / Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. + 46 8 666 02 86	Authorized officer  Karin Säfsten Telephone No. + 46 8 782 25 00

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/DK 97/00412

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	<p>Patent Abstracts of Japan, abstract of JP 1-48692 A (MITSUBISHI HEAVY IND LTD), 23 February 1989 (23.02.89)</p> <p>--</p>	1,3
A	<p>Patent Abstracts of Japan, abstract of JP 56-122690 A (NIPPON DENKI K.K.), 26 Sept 1981 (26.09.81)</p> <p>--</p> <p>-----</p>	1-7

**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

03/02/98

International application No.

PCT/DK 97/00412

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 4034745 A1	18/07/91	NONE	
DE 2713904 A1	05/10/78	NONE	
US 5521352 A	28/05/96	EP 0723491 A WO 9508414 A	31/07/96 30/03/95



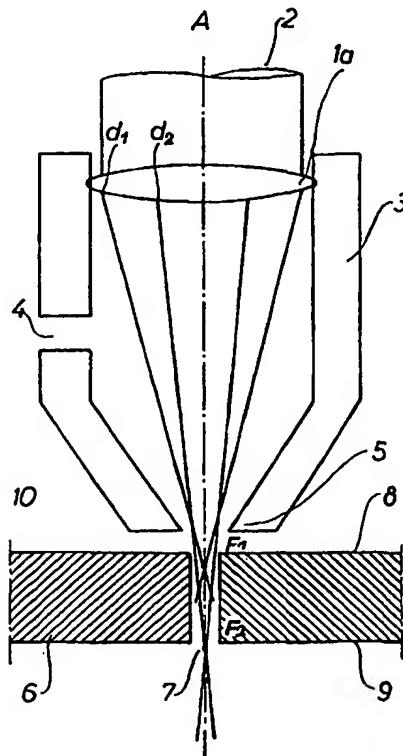
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : <b>B23K 26/06</b>		A1	(11) International Publication Number: <b>WO 98/14302</b>
			(43) International Publication Date: 9 April 1998 (09.04.98)
(21) International Application Number: <b>PCT/DK97/00412</b>		(81) Designated States: AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GE, GH, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).	
(22) International Filing Date: 30 September 1997 (30.09.97)			
(30) Priority Data: 1067/96 30 September 1996 (30.09.96) DK 1091/97 23 September 1997 (23.09.97) DK			
(71) Applicant (for all designated States except US): FORCE INSTITUTTET [DK/DK]; Park Alle 345, DK-2605 Brøndby (DK).		Published With international search report. With amended claims. In English translation (filed in Danish)	
(72) Inventor; and (75) Inventor/Applicant (for US only): NIELSEN, Steen, Erik [DK/DK]; Nyvej 4, Meløse, DK-3320 Skævinge (DK).			
(74) Agent: CHAS. HUDE A/S; H.C. Andersens Boulevard 33, DK-1553 Copenhagen V (DK).		Date of publication of the amended claims: 7 May 1998 (07.05.98)	

## (54) Title: A METHOD OF PROCESSING A MATERIAL BY MEANS OF A LASER BEAM

## (57) Abstract

A method of processing a material with a first and a second surface (8, 9) by means of a laser beam (2), which is focused by means of a multilens objective in a number of focal points ( $F_1, F_2 \dots F_n$ ), which are approximately positioned on a common axis with an angle to the first surface (8). The focal points are spaced apart and used for cutting plates, several focal points being utilized for melting/cutting the plate material. As a result a good cutting notch is obtained with a poor adhering of slags and a good separation of the cut parts.



**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakhstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		

**AMENDED CLAIMS**

[received by the International Bureau on 20 March 1998 (20.03.98);  
original claims 1-7 replaced by new claims 1-6 (2 pages)]

1. A method of processing a material with a first and a second surface (8, 9) by means of a laser beam (2), which for instance by means of a multilens objective is focused in a number of focal points ( $F_1, F_2, \dots, F_n$ ), which are positioned approximately on a common axis forming an angle with the first surface, and which are spaced apart relative to one another, used for cutting plates, several focal points being utilized for melting/cutting the plate material, the central portion of the laser beam (2) being focused in the focal point ( $F_1$ ) adjacent the second surface (9).
- 10 2. The use as claimed in claim 1, characterised in that the focal points ( $F_1, F_2, \dots, F_n$ ) are fixed spaced apart from one another and from the first and the second surface (8, 9).
3. The use as claimed in claim 1 or 2, characterised by the number of focal points ( $F_1, F_2, \dots, F_n$ ) being two.
- 15 4. The use as claimed in one of the preceding claims 1 to 3, characterised by at least one of the focal points ( $F_1, F_2, \dots, F_n$ ) being positioned between the first and the second surface (8, 9) adjacent the second surface (9) or adjacent the first and the second surface, respectively.
- 20 5. The use as claimed in one of the preceding claims 1 to 4, characterised by the focal point ordinarily being positioned adjacent the second surface (9) during the starting of the cutting being caused to be positioned on the first surface (8).
6. The use as claimed in one of the preceding claims 1 to 5, characterised by the focusing optical instruments (1a, 1b, 21a, 21b) focusing the laser beam (2) in several focal points ( $F_1, F_2, \dots, F_n$ ), the

10

distance of which from the second surface (9) being increased concurrently with the increasing distance of the light from the central axis of the laser beam.